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AN APPROACH TO EFFECTIVE UHF (S/L BAND) DATA COMMUNICATIONS FOR SATELLITE PERSONAL COMMUNICATION SERVICE (PCS)

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An Approach to Effective UHF (S/L Band) Data Communications for Satellite Personal Communication Service (PCS)

Land Mobile Service (LMS) satellite systems (SSs) providing Personal Communication Service (PCS), now under development after FCC authorization, could offer packet data communication service with an ecomomy exceeding that of conventional circuit-switched data carrying connections in voice channels. The subject access method allows users with personal digital assistants (PDAs), notepad/notebook personal computers (PCs) and PCs in general, to access such LMS SSs. Users can directly access the non-geosynchronous space vehicle (SV) constellation of an LMS SS to perform non-interactive processing functions. Examples are the execution of agent-based applications that exploit the client-agent-server paradigm, such as[1] "ORACLE in Motion"™, and the transfer of[2] computer-processed dictation of speech in text form on an anywhere-anytime basis.

Users that can access the non-geosynchronous SV constellation are mobile and/or fixed. The users are located in any of a large number of earth-based cells organized and serviced, through narrow beam antennas, by the SV constellation of the LMS provider. Frequency reuse may be performed on a 1 for 7 basis for time divided (TD) access or 1 for 1 for code divided (CD) access. The forward path, i.e., Gateway (GW) hub-to- SV-to-cell/user, at S-band is organized into frequency division (FD) channels and, within each such channel, either time division (TD) or code division (CD) is employed. The return path, i.e., user/cell-to-SV-to-GW hub, at L-band is also organized into FD channels with either TD or CD for users to access any one SV of a constellation.

The UHF transmission media and the problems associated with signaling through such fading media have been reported by many investigators. Lutz[3] et al report their findings and conclude that, " Moreover, the models show that reliable and efficient data transmission via the land mobile satellite channel should be achievable, if the transmission scheme is suitably adapted to the channel behavior." It is clear that an understanding of the UHF channel is necessary and adaptation to the vagaries of the channel is essential in achieving reliable communication.

A brief investigation of the recent literature dealing with fading media modulation/demodulation techniques revealed the approach traditionally employed in addressing this problem. As summarized in Fig 1, modulation/demodulation techniques are traditionally selected on the basis of the relation between the symbol rate and Doppler or the signaling bandwidth to the coherence bandwidth. Since modulation/demodulation techniques used for signaling in a fading media cannot address all the problems, such as fading with all its vagaries, these are addressed through support techniques for fading media modulation/demodulation. These include the traditional arsenal used for HF and troposcatter at UHF, such as diversity, equalization, and error correction with interleaving and transmission strategies, such as the use of pilot tones. Pulse shaping and symbol constellation designs are part of this arsenal as well. Satellite transponder technology through development of linearized characteristics may offer an opportunity to reduce intermodulation in frequency division schemes for multiple access. These macro-level enhancement techniques are moving towards adapting to the media through techniques such as [4] decision feedback channel estimation and [5] adaptive equalization methods. The symbol constellation design is another effort in the adaptive direction.

Under the sponsorship of NASA Small Business Innovation Research (SBIR) Contract NAS7-1335, Information Systems International (ISI) has been exploring methods to achieve reliable, economical data communication by packet tranmission through LMS SSs offering PCS capability. Signaling functions that adapt to the vagaries of the UHF mobile satellite channel essential in the design of such a PCS via LMS SSs have been studied. Efficient design of packet data communication service over a LMS SS requires addressing a group of users in a cell. Severe latency grievously multiplies, if sequential methods are used to coordinate PCS data communication with each user in a cell. If PCS activities in a cell are coordinated through addressing a group, what percentage of the users will receive the information without error? System solutions are available to handle those that did not receive the information, but basic UHF transmission knowledge is required to understand the extent. Exceptions have to be made for those that did not receive coordinating information due to media vagaries. For that matter, on a point-to-point basis how reliable is the transfer of information for signaling functions? Is there a way to avoid the use of ACKs and NAKs, as in the case of high level data link control (HDLC) adapted to such Mobile Satellite Service (MSS) channels with non-geo SVs, either MEO (medium earth orbit) or LEO (low earth orbit)?

Fig 2 shows the latencies attendant with transmission times for MEO and LEO SVs servicing Boston-and Miami-based users. The MEO example has an on-board control function for the satellite PCS and latency for this case would include on-board processing time and propagation delay times; in the figure, only the propagation times are considered. In the case of the LEOs, the satellite PCS control function is assumed to be performed at a gateway (G), which happens to be located in Washington, DC. A Miami-based user thus incurs the delay from Miami to the gateway, i.e., $\rho_{ML} + \rho_{GL}$, and the delay from the gateway to Boston, i.e., $\rho_{GL} + \rho_{BL}$. The figure shows the time axis starting at the time of ascending node crossing, at longitude -90 deg, of the first satellite of the LEO constellation. Data for this figure was generated by means of an ISI-developed APL2 program called TRAKCS.

In more aggressive moves, ISI has been investigating the feasibility of employing TRAKCS to operate in conjunction with a geographic information system (GIS), such as[6] SPANS (AIX, OS/2, DOS)*, to determine the user's environment for effective use of packet data service via LMS SSs providing PCS. In such systems, user activities in a cell are controlled from the hub (i.e., GW) location for the hub-and-spoke satellite system architecture which all currently authorized systems adopt. This arrangement is suited for operating a combined TRAKCS and GIS to establish a profile of the user's environment and the possible signaling environment for conducting system signaling functions. Through GIS and a user-position location system, such as the radio determination satellite service (RDSS), the user's environment--whether open highway, urban, or suburban--can be determined. Through TRAKCS and GIS, the elevation angle of a non-geosynchronous SV from the user can be determined to adapt the communication process.

Fig 3 shows the elevation angles observed at Miami, Washington, and Boston for the same LEO constellation and time span of Fig 2. Gaps in coverage are supported by SVs in adjacent orbital planes of the LEO constellation, which is not shown in Fig 3 (adjacent plane SV coverage is illustrated by the dashed curve of Fig 2). Users in a cell will have similar elevation angle profiles and users that view the non-geosynchronous SV at higher elevation angles, e.g., 35 deg, are expected, in general, to have the benefit of better satellite channels. A possible method of adapting the satellite PCS data communication system is to employ the HDLC ACKs and NAKs only when the user elevation angle is below, say, 35 deg. The packet data communication control function has the option to employ or not to employ the ACK/NAK mode, depending on its assessment of the user environment and the user-to-SV elevation angle profile.

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* SPANS is a registered trademark of INTERNA TYDAC Technologies, Inc

The other more aggressive approach being pursued is investigation of the physical medium (the so-called "Layer Zero"), identified in the ISO layered architecture for OSI, to correct for fading and related vagaries of the UHF MSS channel. The physical medium in this case is essentially an attempt to make that channel approximate, as closely as possible, a terrestrial 4-wire full duplex (FDX) circuit (as used for Toll Quality transmission by telecommunication carriers or adminisrations) for which the ISO layered architecture was originally formulated. Since this is a process that requires a significant amount of information concerning fade characteristics of the media (including fade duration, occurrence of selective fading, fade depths, fade rates, and other relevent vagaries), a measurement program through a non-geosynchronous satellite with realistic user environments (including user mobility) is required.

The lack of a non-geosynchronous satellite with an S-band forward link and an L-band return link leaves no alternative for consideration but the use of INMARSAT, which operates at L-band only. Through a measurement program, it is hoped that channel fading information can be collected to design a physical layer (the first in the ISO layered architecture), in order to utilize existing network protocols, i.e., the data link layer, which have been extensively developed and refined.

Conclusion

Reliable signaling information transfer is fundamental in supporting the needs of data communication PCS via LMS SSs. The needs of the system designer can be satisfied only through the collection of media information that can be brought to bear on the pertinent design issues. We at ISI hope to continue our dialogue with fading media experts to address the unique data communications needs of PCS via LMS SSs.

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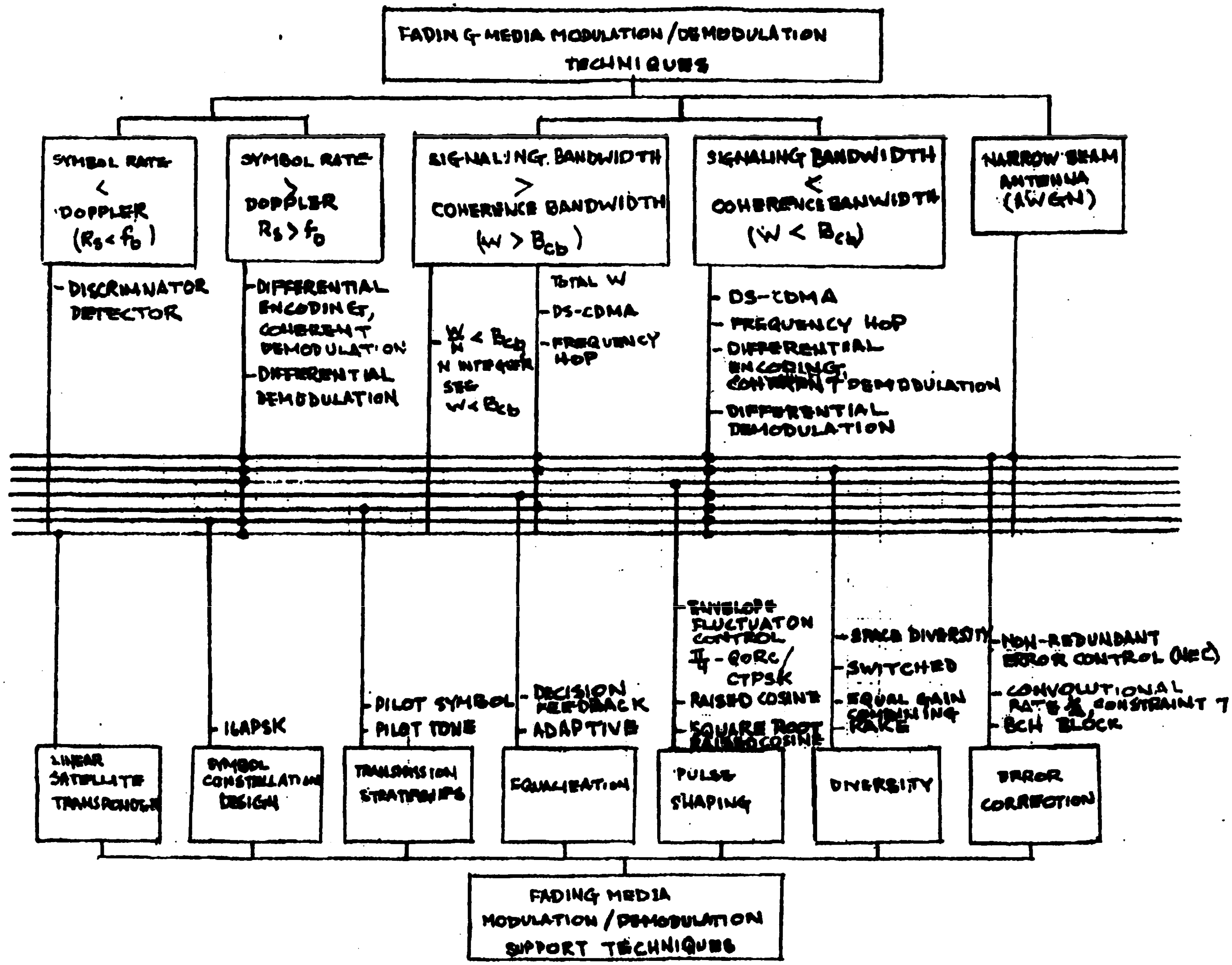

Fig. 1. Modulation / demodulation approaches for access system.

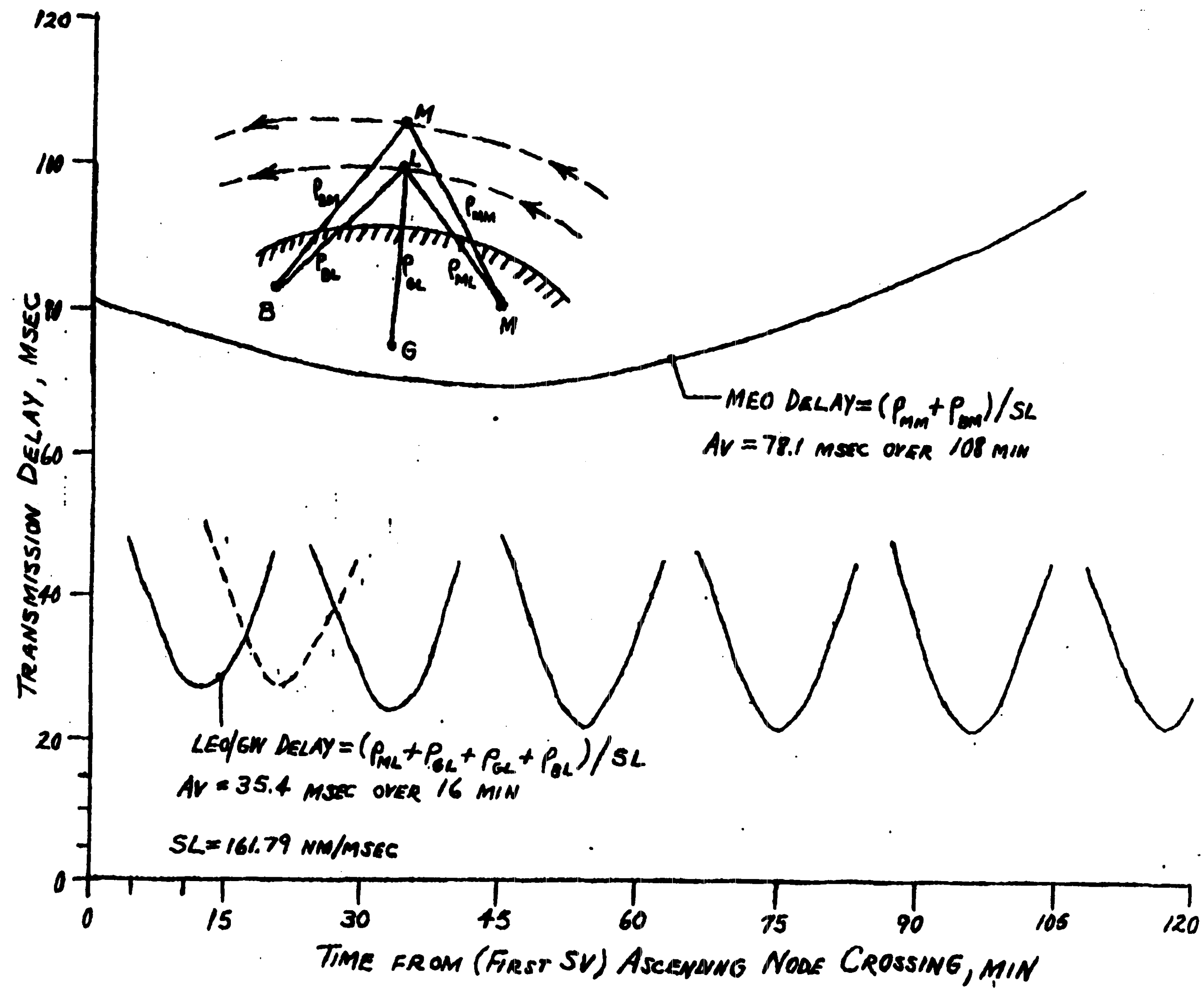

Fig. 2. **Miami to Boston transmission time delays through MEO and LEO/GW.**

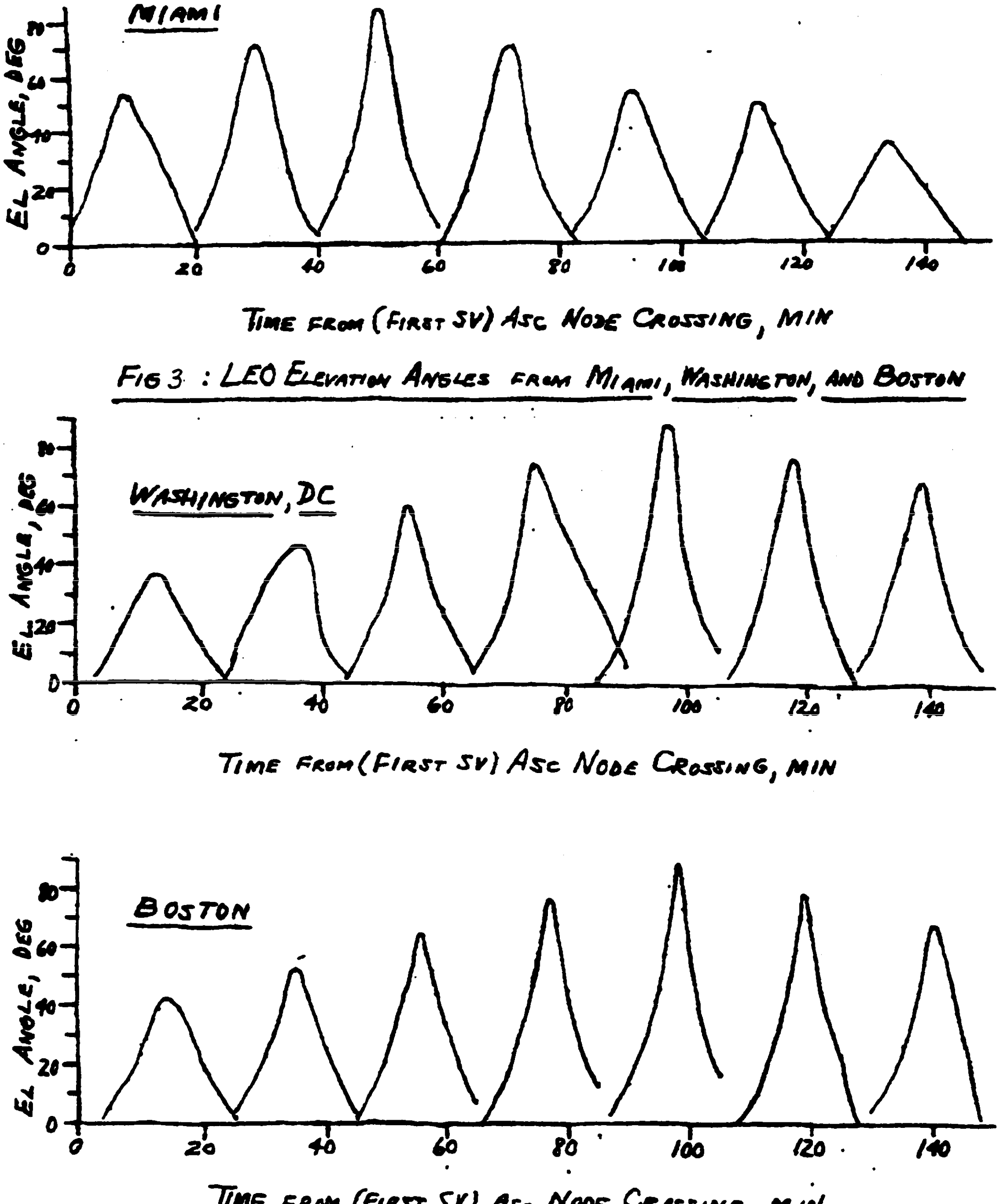

Fig. 3. LEO elevation angles from Miami, Washington, and Boston.